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13. ABSTRACT (Maximum 200 words)

We are addressing some fundamental research issues in modeling, display and simulation for computer-aided design and virtual environments. Our emphasis is to develop better algorithms and software systems and to demonstrate their applications. We are utilizing a number of techniques from algebraic geometry, approximation theory, computational geometry, numerical analysis, computer-aided geometric design and computer graphics to investigate the underlying mathematical concepts and to develop more efficient and robust geometric algorithms. This includes algorithms and systems for computing boundary representations of constructive solid geometry models composed of spline primitives and their boolean combinations. We have developed novel algorithms for boundary computation, model simplification, fast display and interference detection. These include use of exact arithmetic for robust and accurate boundary computation, development of an interactive solid modeler using parallel algorithms and implementations, simplification with guaranteed error bounds for large polygonal models, occlusion culling, interactive display of large spline models and efficient collision detection between general polygonal models. The resulting algorithms and systems have been applied to a number of applications and the technology has been transferred to a number of research and DOD labs as well as commercial vendors.

14. SUBJECT TERMS
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1.   Technical Objectives and Motivation

     We are addressing some fundamental research issues in modeling, display and simulation for computer-aided design and virtual environments. Our emphasis is to develop better algorithms and software systems and to demonstrate their applications.

2.   Approach

We are utilizing number of techniques from algebraic geometry, approximation theory, computational geometry, numerical analysis, computer-aided geometric design and computer graphics to investigate the underlying mathematical concepts and to develop more efficient and robust geometric algorithms. This includes algorithms and systems for computing boundary representations of constructive solid geometry models composed of spline primitives and their boolean combinations. In particular, we propose to compute accurate spline representations of the intersection curve with guaranteed error bounds and make use of a number of algorithms from computational geometry and discrete mathematics to represent the topologies of the given solids. The resulting system is being integrated with BRL-CAD and being applied to computing an accurate boundary representation of a Bradley fighting vehicle. We are also developing improved algorithms for polygon and surface triangulation, simplification, visibility and hierarchical representations for developing interactive systems for displaying large datasets. Eventually, we will interface these systems with the immersive hardware and apply them for interactive walkthrough of the fighting vehicle.

3.   Significant Accomplishments

  The PI and his students have developed novel algorithms for boundary
  computation, model simplification, fast display and interference detection.
   These include use of exact arithmetic for robust and accurate boundary computation,
development of an interactive solid modeler using parallel algorithms and
implementations, simplification with guaranteed error bounds for large polygonal models,
occlusion culling, interactive display of large spline models and efficient collision
detection between general polygonal models.

         The resulting algorithms and systems have been applied to a number of applications and the technology has been transferred to a number of research and DOD labs as well as commercial vendors.

4.   Cooperation with and Technology Transfer to Army Laboratories and Other Or ganizations

  A: Army Research Labs, Aberdeen, MD: The PI and his graduate students
     are integrating our solid modeler, BOOLE, with the BRL-CAD solid modeling
     system developed by researchers at Army Research Labs, Aberdeen.
     BRL-CAD is primarily used for vulnerability analysis at ARL and it
     has more than 1600 users worldwide. BOOLE will be used for performing
     boolean operations on curved surfaces.

  B: Collision Detection System: More than 3700 users all
     over the world have copied the source code of the
     I-COLLIDE, V-COLLIDE, SWIFT and PQP collision detection system.

Some of the prominent users are at Sandia National Labs, Lockheed Martin, Ford Motor Company, Division, Engineering Animation, Army Research Labs, Evans and Sutherland, etc. The system has also been licensed to Mechanical Dynamics Inc. and Division Inc.

C: White Sands Missile Range, NM: The algorithms and systems for collision detection have been incorporated into a missile distance display scenario. The purpose of the scenario is to produce a visual display of the results of an engagement between a missile and a target. The main objective is to provide information in sufficient detail to permit missile system performance evaluation.

D: Lockheed-Martin, Electric Boat and Newport News Shipbuilding: The PI and his students have been actively collaborating with researchers at these organizations and other universities for more than two years as part of ARPA's project on Simulation-based Design. In particular, the software technology for model generation, simplification and fast display is being used for interactive walkthrough of submarines and ship-models.

E: Air Force's Philip Laboratory, NM: The solid modeling and fast rendering systems, developed at UNC, are used for model generation and fast display of satellite systems.

5. Publications in Refereed Journals and Conference Proceedings

1. S. Krishnan, D. Manocha, M. Gopi, T. Culver and J. Keyesr (2001) "BOOLE: A Boundary Evaluation System for Boolean Co mbinations of Sculptured Solids", International Journal on Computational Geometry and Applications, 31 pages.

2. J. Cohen, D. Manocha and M. Olano (2001) "Successive Mappings: An Approach to Polygon Mesh Simplification with Guara nteed Error Bounds", International Journal on Computational Geometry and Application, 2001, 37 pages.

3. J. Keyser, T. Culver, D. Manocha and S. Krishnan (2000) "Efficient and Exact Manipulation of Algebraic Points and Cu rves", Computer-Aided Design, vol. 32, no. 11, pp. 649-662, 2000. Special issue on Robustness.

4. S. Krishnan and D. Manocha (2000) "Hidden surface removal algorithms for sculptured models", Graphical Models and Im age Processing, vol. 62, no. 4, pp. 283-307, 2000.

5. A. Gregory, A. State, M. C. Lin, D. Manocha and M. Livingston, "Interactive Surface Decomposition for Polyhedral Mor phing", Visual Computer, vol. 15, pp. 453-470, 1999.

6. M. Gopi and D. Manocha (1999) "Simplifying Spline Models", Computational Geometry: Theory and Applications, vol. 14, pp. 67-90, 1999.

7. K. Hoff, T. Culver, J. Keyser, M. Lin and D. Manocha, "Fast Computation of Generalized Voronoi Diagrams using Graphi cs Hardware", Proceedings of ACM SIGGRAPH, 1999.

8. J. Keyser, S. Krishnan and D. Manocha (1999) "Efficient and Accurate B-rep Generation of Low Degree Sculptured Solid s Using Exact Arithmetic:I - Representations", Computer-Aided Geometric Design, 23 pages.

9.   J. Keyser, S. Krishnan and D. Manocha (1999) "Efficient
and Accurate B-rep Generation of Low Degree Sculptured Solid
s Using Exact Arithmetic:II - Computation", Computer-Aided Geometric
Design, 25 pages.

10.   A. Wilson, E. Larsen, D. Manocha and M. Lin, "Partitioning
and Handling Massive Models for Interactive Collision Det ection", Computer Graphics
Forum, 1999.

11.   S. Kumar, D. Manocha, W. Garrett and M. Lin (1999)
"Hierarchical Backface Computation" Computer and Graphics, Specia l Issue on Visibility,
1999.

12.   A. Wallack and D. Manocha (1998) "Robust Algorithms for
Object Localization", International Journal on Computer Visi on, vol. 27, no. 3, pp. 243-
262.

13. Erikson, D. Manocha and B. Baxter, "HLODs for Faster Display
of Large Static and Dynamic Environments", Proc. of ACM Sym posium on Interactive 3D
Graphics, 2001.

14.   B. Baxter, V. Scheib, M. Lin and D. Manocha, "DAB:
Interactive Haptic Painting with 3D Virtual Brushes", Proc. of AC M SIGGRAPH, 2001, to
appear.

15.   K. Hoff, A. Zaferakis, M. Lin and D. Manocha, "Fast and
Simple 2D Geometric Proximity Queries using Graphics Hardwar e", Proc. of ACM Symposium
on Interactive 3D Graphics, 2001.

16.   S. Krishnan, M. Foskey, T. Culver, J. Keyser and D.
Manocha, "PRECISE: Efficient Multiprecision Evaluation of Algebr aic Roots and Predicates
for Reliable Geometric Computation", Proc. of ACM
Symposium on Computational Geometry, 2001.

17.   A. Gregory, A. Mascarenhas, S. Ehmann, M. C. Lin and D.
Manocha, ""6-DOF Haptic Display of Polygonal Models", Proc.
of IEEE Visualization, 2000.

18.   A. Wilson, M. Lin, D. Manocha, B. Yeo and M. Yeung,
"Video-based Acceleration Algorithms for Interactive Display of Large Models", Proc. of
ACM Multimedia, pp. 75-84, 2000.

19.   C. Pisula, K. Hoff, M. Lin and D. Manocha, "Randomized
Path Planning for a Rigid Body based on Hardware Accelerated Voronoi Sampling", Proc. of
4th International Workshop on Algorithmic
Foundations of Robotics, 18 pages, 2000.

20.   K. Hoff, T. Culver, J. Keyser, M. Lin and D. Manocha,
"Interactive Motion Planning using Hardware Accelerated Comput ation of Generalized
Voronoi Diagrams", Proc. of IEEE International
Conference on Robotics and Automation, 2000.

21.   E. Larsen, S. Gottschalk, M. Lin and D. Manocha, "Fast
Distance Queries using Rectangular Swept Sphere Volumes", Pro c. of IEEE International
Conference on Robotics and Automation, 2000.

22.   D. Aliaga, J. Cohen, A. Wilson, E. Baker, H. Zhang, C.
Erikson, K. Hoff, T. Hudson, W. Stuerzlinger, R. Bastos, M. W hitton, F. Brooks and D.
Manocha, "A Framework for the Real-Time
Walkthrough of Massive Models", Proc. of ACM Symposium on Interacti ve 3D Graphics, 1999.

23.   C. Erikson and D. Manocha, "GAPS: General and Automatic Polygon Simplification", Proc. of ACM Symposium on Interacti ve 3D Graphics, 1999.

24.   T. Culver, J. Keyser and D. Manocha, "Accurate Computation of Medial Axis of a Polygon, Proc. of ACM Symposium on So lid Modeling, 1999.

6. HONORS and AWARDS

2002: Best Panel Award, IEEE Visualization

2001: Best Paper Award, ACM Multimedia Conference

1999: Best Paper Award, Eurographics Conference

7.   Papers or reports in non-refereed publications

8.   Books or book chapters published

1. Applied Computational Geometry: Towards Geometric Engineering}, edited by Ming C. Lin and Dinesh Manocha, Springer-Verlag , 1996.

2. Applications of Computational Algebraic Geometry by, David Cox, Bernd Sturmfels, Dinesh Manocha, Thomas Sederberg, Xenia Kramer, Rienhard C. Laubenbaches, Rekha Thomas and John Little, American Mathematical Society, 1997.

3. Interactive Walkthroughs of Large Geometric Datasets, edited by Dinesh Manocha. ACM SIGGRAPH Course, 1999.

4. Interactive Walkthroughs of Large Geometric Environments, edited by Dinesh Manocha and Daniel Aliaga. ACM SIGGRAPH Course , 2000.

5. Interactive Walkthroughs of Large Geometric Datasets, edited by Dinesh Manocha. ACM Solid Modeling Course, 2001.

9.   Patent/Inventions filed or granted

10. Number of graduate and undergraduate students supported by gender and by minority group

11. Number of MS and Ph.D. degrees awarded to students working through the gran t and their current employment status and employers

1. Jonathan Cohen (Ph.D. December '98). Assistant Professor at Johns Hopkins Univ.
2. Tim Culver (Ph.D. Fall'00). Working at Think3 Inc.
3. Carl Erikson (Ph.D. Spring'00). Working at BOPS Inc.
4. Stefan Gottschalk (Ph.D. Summer'00; Co-Supervised with Ming Lin). Working at Nvidia Inc.
5. Shankar Krishnan (Ph.D. July '97). Member of Technical Staff, AT & T Research Labs.

6. Subodh Kumar (Ph.D. Fall '96). Assistant Professor at Johns Hopkins Univ.
7. Eric Larsen (M.S. Spring'99). Working at Sony.
8. Atul Narkhede (M.S. Spring '95). Working at Silicon Graphics.
9. Amol Pattekar (M.S. Spring'98). Working at Yahoo Inc.
10. Kris Ponamgi (M.S. Fall '95). Working at Virtus Inc.
11. Kyle Wilson (M.S. Summer '97). Working at Interactive Magic.
12. Hansong Zhang (Ph.D. Fall '98). Working at NVIDIA Inc.

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